2/26/07 CD

MEMORANDUM

INTERMOUNTAIN POWER SERVICE CORPORATION

TO: George W. Cross

FROM: Dennis K. Killian

DATE: February 22, 2007

SUBJECT: Proposed Scrubber Reaction Tank Forced Oxidation - Defoamer Test

Please sign below indicating your approval to conduct the proposed test outlined in this memo. The proposed test will study the effects, if any, of overdosing the reaction tanks with defoamer on the forced oxidation gypsum reaction. This test should not affect removal or compliance.

There has been some empirical data gathered that would indicate a correlation between continuous addition of defoamer and poor oxidation results. The problem with the gathered data is that there were too many uncontrolled variables to truly understand their effects on the process. It is the goal of this test to limit the influence of these variables and to study the direct effects of defoamer on oxidation rates.

Setup

- ☐ The test will begin with lab personnel taking slurry samples from all eight operating scrubber module reaction tanks. These samples will be processed using thermogravimetric analysis to determine the gypsum purity.

- ☐ Four modules will be selected from this pool to be used in this study. The two reaction tanks with the highest gypsum purity will be placed in "Category A." The two modules with the lowest gypsum purity will be placed in "Category B."

- ☐ At the same time that lab personnel takes these samples, other information will be collected as per the attached data sheet labeled "Lab Data." This information will be collected at the beginning of each shift during the testing period. The lab will also collect samples at the beginning of each shift and analyze one of the samples per day. The other sample will be saved for analysis at a later time if needed to validate trends.
- ☐ On the scheduled start day, I&C will clean and calibrate the pH probes on the four designated modules.

Category A

- ☐ Operations should make every effort to keep conditions constant on these modules during this test. This includes:

    - Oxidation air flows kept constant. Do not swap blowers or change the balance of air flows. Keep oxidation air flows to the test modules balanced at 1200 ± 100 SCFM.

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- Any amount of defoamer added by hand during the test period should be logged. The amount of defoamer added by hand should be minimized. Add no more than 1/2 gallon at a time. If possible, wait 15 minutes between dosing to ensure that more is actually needed.

- Keep pH constant.

☐ The two reaction tanks with the highest gypsum purity will be fed defoamer at the highest rates possible using the metering pumps. Both stroke and speed should be turned up to the highest setting.

☐ If the forced oxidation levels begin to drop off, wait until the gypsum purity reaches 70 percent or lower. Once this is achieved shut off the defoamer pumps.

☐ From this point on, only add defoamer manually and only when absolutely required.

☐ Continue this course until gypsum purity reaches 90 percent. This will conclude the testing for Category A.

☐ The test will terminate after three days if oxidation does not change by more than 10 percent or after one week.

<u>Category B</u>

☐ Operations should make every effort to keep conditions constant on these modules during this test. This includes:

- Oxidation air flows kept constant. Do not swap blowers or change the balance of air flows. Keep oxidation air flows to the test modules balanced at 1200 ± 100 SCFM.

- Any amount of defoamer added by hand during the test period should be logged. The amount of defoamer added by hand should be minimized. Add no more than 1/2 gallon at a time. If possible, wait 15 minutes between dosing to ensure that more is actually needed.

- Keep pH constant.

☐ The two reaction tanks with the lowest gypsum purity should only have defoamer added manually and then only when it is absolutely required.

☐ If the forced oxidation levels begin to improve, wait until the gypsum purity reaches 90 percent or higher. Once this is achieved, feed defoamer at the highest rates possible using the metering pumps. Both stroke and speed should be turned up to the highest setting.

☐ Continue this course until gypsum purity drops below 70 percent. This will conclude the testing for Category B.

☐ The test will terminate after three days if oxidation does not change by more than 10 percent or after one week.

The designated Lab Personnel and Scrubber Operators will be contacted daily by Engineering Services to check on status and answer any questions.

Any questions regarding this test plan may be directed to Bret Kent at extension 6447.

George W. Cross

George W. Cross
President and Chief Operations Officer

2/26/07
Date

BK/DEW:jmj
cc: Jon A. Finlinson
Cindy Jones

LAB DATA SHEET
Scrubber Defoamer Testing

Group A

Date	Time	Unit	Module	% Purity	Meter pH	Lab pH	% Solids	Conductivity	Defoamer Pump Setting

LAB DATA SHEET
Scrubber Defoamer Testing

Group B

Date	Time	Unit	Module	% Purity	Meter pH	Lab pH	% Solids	Conductivity	Defoamer Pump Setting

OPERATIONS DATA SHEET
Scrubber Defoamer Testing

Unit 1

Date	Time	Module	Amount of Defoamer Added

OPERATIONS DATA SHEET
Scrubber Defoamer Testing

Unit 2

Date	Time	Module	Amount of Defoamer Added

5/15/07 CD

MEMORANDUM

INTERMOUNTAIN POWER SERVICE CORPORATION

TO: Jon A. Finlinson

FROM: Dennis K. Killian

DATE: May 15, 2007

SUBJECT: Results from the Effects of Defoamer on Reaction Tank Oxidation Purity Study

Please find attached the above referenced study report and recommendations. Any questions regarding the report may be directed to Bret Kent at extension 6447.

BK/JKH:jmj

cc: Richard Schmit - w/ 6 copies of attachment
Bret Kent
Cindy Jones
Norm Hess (GE Infrastructure)

Effects of Anti-Foam use in Scrubber Reaction Tanks on Gypsum Purity

INTERMOUNTAIN POWER SERVICE CORP.

 Date: March 2007

Executive Summary

Based on the results from the March 2007 study, Technical Services offers the following guidelines for the use of defoamer in scrubber reaction tanks. These guidelines are intended to maximize gypsum purity (% oxidation) in the scrubber slurry, which in turn will improve sludge dewatering operations.

The recommended application rates provided below should only be implemented when needed and then be turned back off. Manual or batch dosing is preferred. It is also recommended that all dosing be logged and monitored.

All application of defoamer in the scrubber reaction tanks should be minimized and used only when needed. Caution should be taken to monitor cumulative effects of heavy application for defoamer in one (1) or more modules. If more than typical amounts are being applied, request assistance from the lab to monitor oxidation purity numbers.

A. Hand/batch feed using quantities less then one (1) quart, do not exceed **four (4) gallons/24hrs**.

B. Continuous addition of 10 mL/min could be used indefinitely.

C. Continuous addition of 20 mL/min should not be done for more than **six (6) shifts**.

D. Continuous addition of 30 mL/min should not be done for more than **three (3) shifts**.

Test Overview

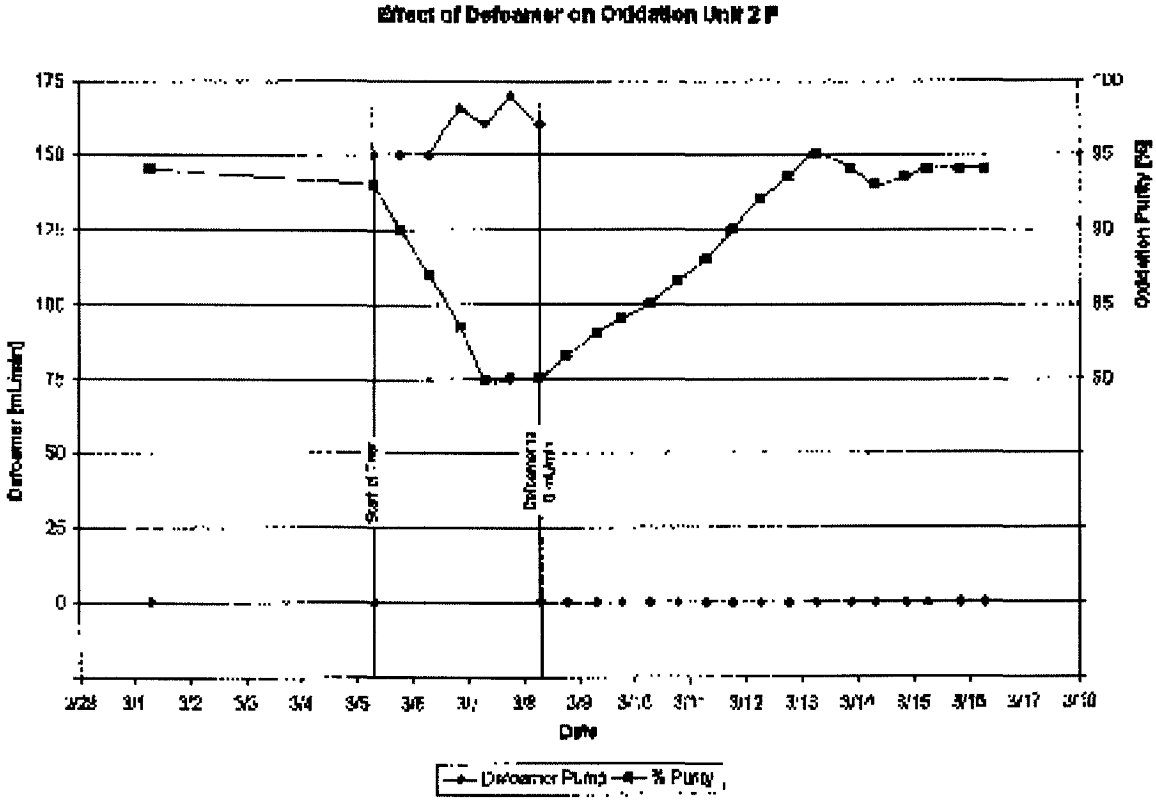
The purpose of this study was to verify the effects of GE Infrastructure FoamTrol AF2290 anti-foaming agent on scrubber reaction tank gypsum purity (% oxidation). Because of the dynamic nature of the reactions taking place inside an absorber module, the test was designed to rule out the effects of changes in process variables. Gypsum purity is critical in reducing scaling of the Scrubber modules and in effective dewatering of the sludge in Sludge Conditioning.

Two (2) groups were monitored. Group A consisted of the two (2) modules with the highest gypsum purity at the start of the test. Group B consisted of the two (2) modules with the lowest gypsum purity at the start of the test. These groups were manipulated by adjusting the feed rate of the AF2290 as follows.

<u>**Phase 1**</u>

To begin the test, Group A (Unit 1 A and Unit 2 F modules) was fed excessive amounts of defoamer at the rate of 125-160 mL/min (48-60 gallons/day). Group B (Unit 1 D and Unit 2 E modules) had defoamer pumps shutoff and all manual additions were carefully monitored.

Phase 2
Once gypsum purity had been affected by a minimum of 10 percent, the process was reversed as follows: Once Group A reached purity levels of 85 percent or less, the defoamer pumps were shutoff and all manual additions carefully monitored. Once they returned to a purity greater than 93 percent, the test for this group was terminated.



Once Group B had reached purity levels greater than 93 percent, its defoamer pumps were turned on and fed the AF2290 at the rate of 10 mL/min (3.8 gallons/day). If the 10 percent change could not be realized, the feed rates were incremented. The purpose of this exercise was to quantify an acceptable constant feed rate.

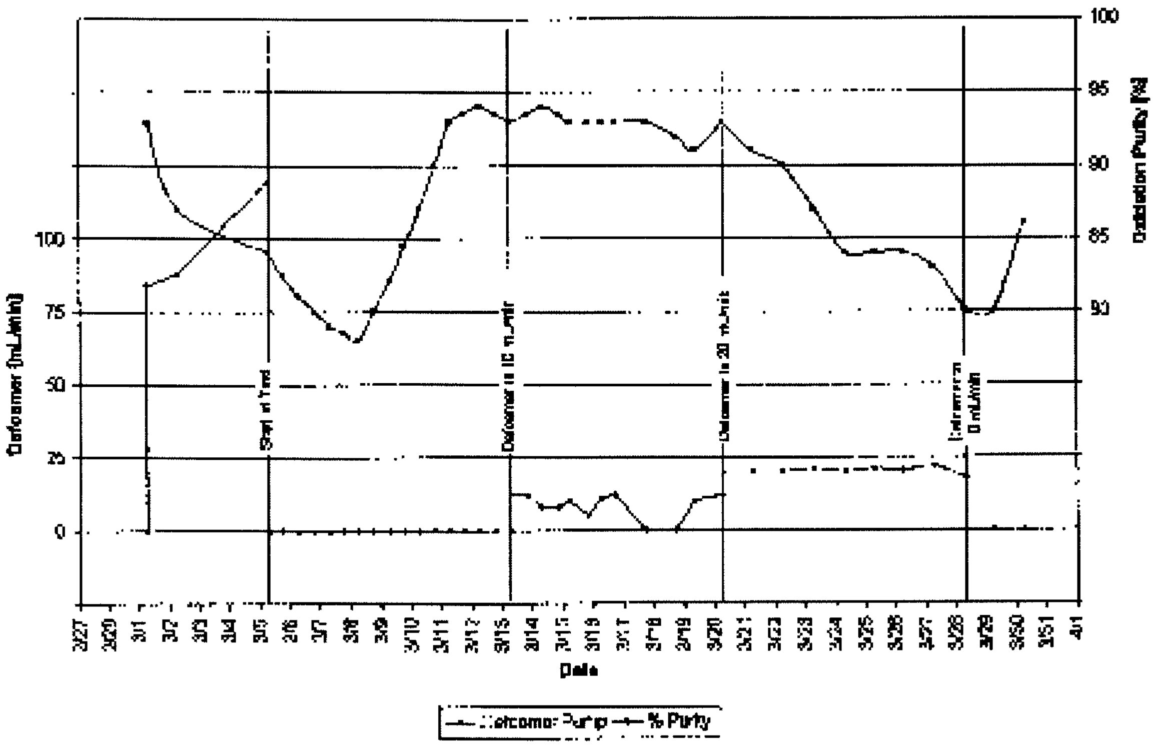
Test Results

Group A
As can be seen from the following graphs the addition of large quantities of AF2290 resulted in a significant decrease of oxidation purity.

Note the rapid decrease in oxidation purity versus the time required for recovery. This lag indicates a buildup in concentration of AF2290. The time required for recovery is dictated by the turnover rate of the reaction tank.

The graph for Unit 2F reinforces the suggestion that the oxidation purity is directly correlated to the concentration of AF2290. Notice that the purity leveled off at 80 percent. This strongly suggests that the concentration of defoamer is controlled or maintained by the addition rate as compared to the reaction tank turnover rate. Additionally, the attainable oxidation purity is directly affected by the level of AF2290 concentration allowed. Once the concentration level reaches a sustainable equilibrium, as dictated by the tank turnover rate, oxidation purity will also balance out.

Effect of Defoamer on Oxidation Unit 1 D



Group B

This group yielded the most interesting results and provides the most information to allow conclusions that will provide operation guidelines for the use of AF2290.

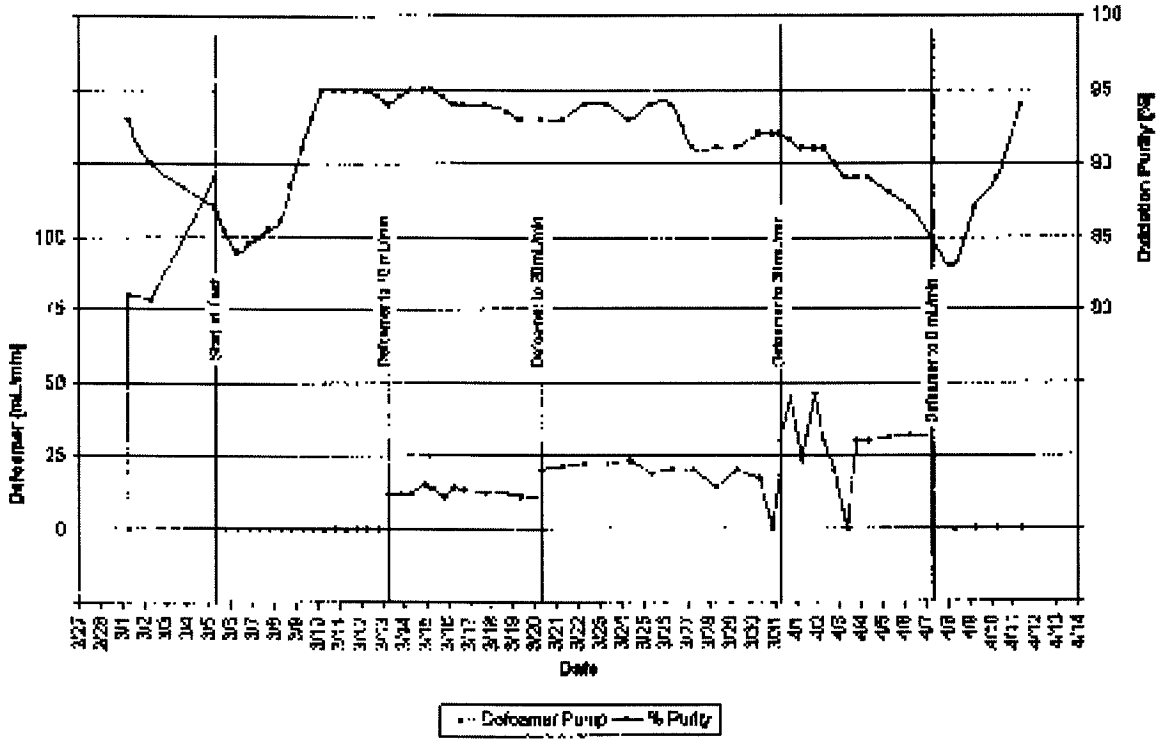
Little to no change was evident in the oxidation purity for an AF2290 addition rate of 10 mL/min to Unit 1D module. Once the addition rate was increased to 20 mL/min, a dramatic change in purity is clearly visible. From this snapshot it appears that under typical operating conditions the deflection point for oxidation purity in relation to the addition rate of AF2290 is between 10 and 20 mL/min.

Effects of Anti-Foam use in Scrubber Reaction Tanks on Gypsum Purity

INTERMOUNTAIN POWER SERVICE CORP.

 Date: March 2007

Effect of Defoamer on Oxidation Unit 2 E



Per the conclusion made from the previous graph (Unit 1D), Unit 2E should have seen similar results for AF2290 feed rates of 20 mL/min. Instead, for a period of nearly a week, oxidation purity cycles up and down. Finally, on March 26 there is a marked change in purity, but then it appears to level out again. Only after the feed rate is increased to 30 mL/min does the trend finally move as expected.

The results of this graph generate more questions than answers. What happened on March 26 to cause the sudden shift in purity? Why would this reaction tank tolerate a higher AF2290 addition rate?

Effects of Oxidation Air and pH

Oxidation purity can be affected by many factors. The factors that can be controlled and are concretely known to directly render change are:

1. Slurry pH
2. Oxidation Air flows
3. Concentration of AF2290

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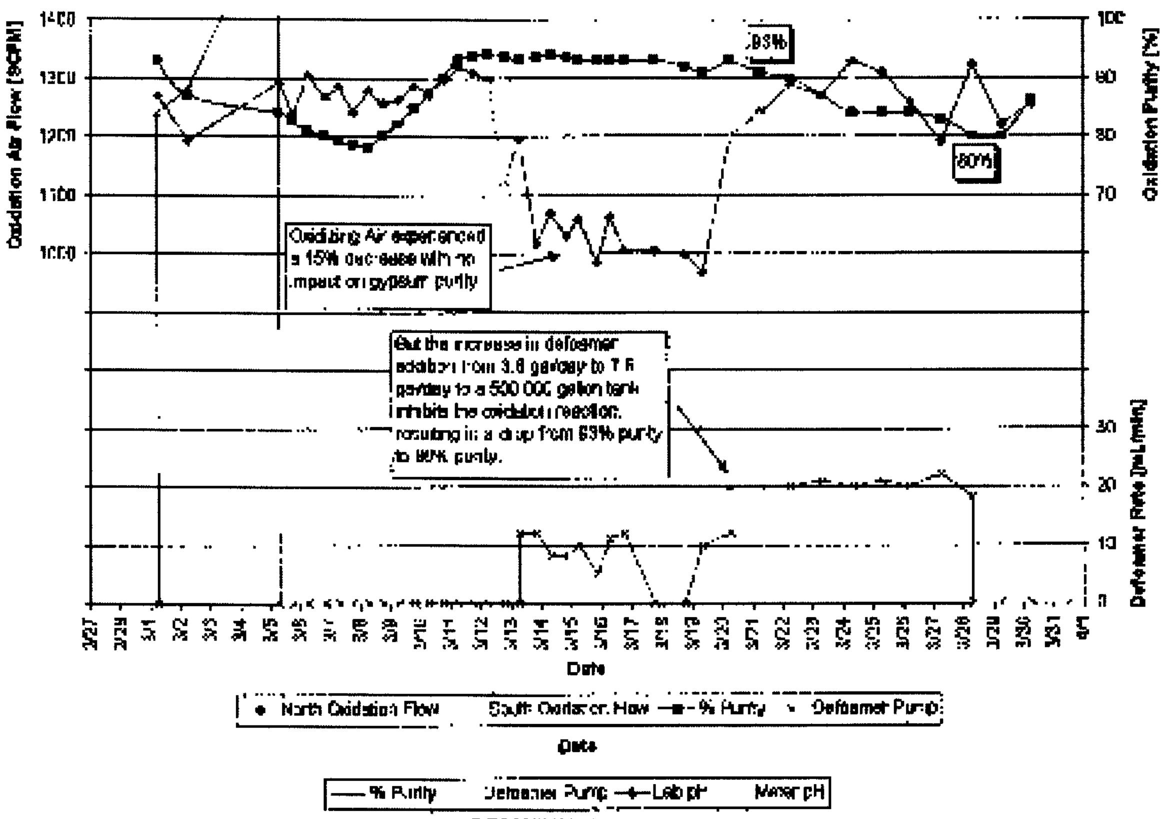
Factors where control is limited or that are currently fixed:

A. Tank Height/Liquid Level

B. Oxidation Air bubble size/distribution

The following graphs will demonstrate the effect of items 1 and 2 from above and attempt to answer the questions raised by the results from Unit 2E.

Effect of Defoamer vs Oxidizing Air - Unit 1 D



Notice that while feeding 10 mL/min of AF2290, the oxidation air flow was reduced by 15 percent with little or no effect on the purity. This is more an indication that excess oxidation air is being provided, than anything else. But, it does show that the excess air being provided makes the reaction less susceptible to negative impacts as a result of changes in air flow. This provides assurance that changes in air flow during the course of the test had negligible effect on the observed results.

On March 26, a 0.1 pH point difference between the lab pH and the tank meter pH was noted. I&C Technicians cleaned and calibrated the probe which provided more accurate control of the reaction tank pH. As can be seen below, even after increasing the

AF2290 flow rate to 20 mL/min (but prior to the probe calibration) the purity remained unaffected. This appears to be the result of having a significantly lower slurry pH than the desired control target. This low pH resulted in enhanced oxidation purity (lower pH equates to better oxidation purity) which offset the negative impact of the increased defoamer addition. Once the calibration occurred there is an obvious decrease in purity. After this adjustment, the purity stabilized and did not reach the goal of a 10 percent change, so the feed rate was increased to 30 mL/min.

At this point the question still remained, 'why would the defoamer have a greater effect on Unit 1D when compared to Unit 2E?' While it appears that pH had significant impact, the complete answer to this question appears to be outside of the scope of this study. Since all operational data, for these two modules, was similar during the test the answer would seem to lie somewhere in the factors that are harder to control. Because existing level sensors cannot distinguish between foam and liquid level, it is impossible to determine if Unit 1D ran a lower liquid level than Unit 2E. It is more likely that distribution nozzles have failed or plugged in Unit 1D, resulting in weaker oxidation kinetics.

Conclusions

The results show a direct correlation between the amount of defoamer added to each scrubber module and it's corresponding gypsum purity levels. While it is not the only process variable that affects gypsum purity it can directly manipulate it. This is simply a question of residence time in the reaction tanks. A careful look at the liquid balance of a reaction tank identifies four (4) main inputs. Mist Eliminator Wash Water, Recovered Water, Limestone Slurry, and the AF2290. The 2 main outputs are evaporation and overflow.

It is apparent that there is an acceptable level of defoamer addition with regards to gypsum purity. If the level of defoamer addition exceeds an allowable concentration, the only alternatives are to reduce the defoamer feed rate or increase the volume of one or all of the inputs.

The following results are adapted from the attached technical letter dated May 1, 2007 from Norm Hess (GE Infrastructure), who is the supplier of the AF2290. The calculations have been modified to account for the actual volume of the reaction tank and density of the slurry (see the attached Mathcad worksheet).

Depending on the blowdown rate of a reaction tank all constant feed additions of AF2290 will eventually achieve an equilibrium state where the concentration will level off.

Addition Rate [mL/min]	10	20	30	50	75	100	150
Equilibrium [PPM]	25.4	50.8	76.2	127.0	190.5	254.0	381.0

The amount of time it takes to reach this equilibrium point is a natural log function. The following graph will illustrate this. This graph assumes constant overflow of 100 gpm.

As an example, if the AF2290 is being added at 10 mL/min it will take approximately 23 days to reach 100 percent equilibrium (25.4 ppm), or 4.5 days to reach 75 percent of equilibrium.

Conversely, if a quantifiable concentration is present in a given reaction tank, at 100 gpm of overflow, it will take 2.3 days to reduce it by 50 percent.

In addition, it is possible to calculate how long it will take before saturation (or the point at which oxidation purity is jeopardized) is achieved. The following graph assumes that it is a single point deflection. Meaning that it does not gradually or linearly affect purity, rather it appears to be a distinct point somewhere between 10 and 20 mL/min where purity is compromised. The data present up to this point would appear to support this idea.

Since an exact number has not been quantified, a value of 35 ppm (the equilibrium concentration point not quite half way between 10 and 20 mL/min) is used to represent a possible deflection point.

This chart correlates nicely with the data collected during the test. At higher feed rates, changes were noted within 24 hours. Ten (10) mL/min did not show any effect on the purity, but once increased to 20 or 30 mL/min it took less than 24 hours to deflect (the added 15 to 20 ppm needed to reach 35 ppm in less than 24 hours correlates to 20 and 30 mL/min respectively).

Recommendations

The recommended application rates provided below should only be implemented when needed and then be turned back off. Manual or batch dosing is preferred.

All application of AF2290 in the scrubber reaction tanks should be minimized and used only when needed. Caution should be taken to monitor cumulative effects for heavy application of defoamer in one (1) or more modules. If more than typical amounts are being applied, request assistance from the lab to monitor oxidation purity numbers.
If the operational situation requires heavy dosing, it should be offset by increasing the other module inputs by an appropriate amount. This proportion requires an approximate 75 gallon increase in reaction tank overflow per every 10 mL/min above and beyond the indicated defoamer rate given in this report.

Adding defoamer should not become a mechanical part of equipment rounds. Operators should verify the need to add defoamer.

A. Any hand or batch feeding should be done using quantities of one (1) quart or less. Not to exceed **four (4) gallons** cumulative in a 24 hour period. This should be logged and monitored.

B. Continuous addition of 10 mL/min. Could be used indefinitely. Rates should be verified periodically. Be aware that manual addition on top of the 10 mL/min continuous, could cause purity to drop off.

C. Continuous addition of 20 mL/min. Not recommended that this be done for more than **six (6) shifts.** This should be logged and monitored to make sure it gets turned back off.

D. Continuous addition of 30 mL/min. Not recommended that this be done for more than **three (3) shifts**. This should be logged and monitored to make sure it gets turned back off. It is not recommended that continuous feed be performed at rates greater than 30 mL/min.

These recommendations apply specifically to the AF2290 product. Conclusions should not be applied to other defoamer products.

Additionally these recommendations are focused on oxidation purity. While the key factor in dewatering is particle size (oxidation purity), it does not directly guarantee successful dewatering. But without good oxidation purity numbers, existing techniques and equipment do not stand a chance at providing effective dewatering.

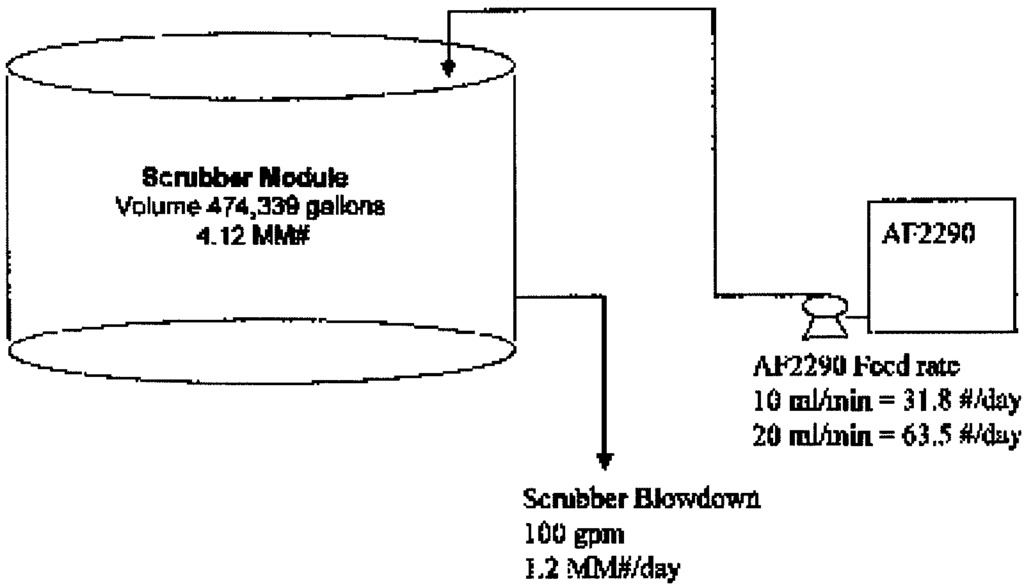
Plans and Goals

Technical Services is working with GE Infrastructure in order to provide a more efficient means of delivering defoamer to each scrubber reaction tank. This will be a semi-automatic batch feed system, with intentions to make it fully automatic at the earliest convenience. The first steps toward this system are already in motion as bulk tanks and recirc pumps are currently (5-3-07) onsite with trial metering pumps in route.

The semi-automatic system will rely on an Operator pushing a button on a local panel to begin a batch feed into a given module. The pump will then meter out a predetermined quantity of AF2290 and shut off. This system will utilize plastic tubing similar to the existing temporary system, but will eliminate the 300 gallon bins and the unreliable metering pumps.

The automatic system will be triggered off of foam level in the tanks and will only meter out the quantity required to keep foam from reaching the roof of the reaction tank.

AF2290 Concentration in Scrubber Reaction Tanks



$D_{tank} = 58 \cdot ft$		Tank Diameter
$H_{tank} = 24 \cdot ft$		Tank Height (to overflow)
$V_{tank} := \frac{\pi}{4} \cdot D_{tank}^{2} \cdot H_{tank}$	$V_{tank} = 474339\,gal$	Tank Volume
$Vdot_{bd} = 100 \cdot gpm$		Tank Overflow (typical)
$Vdot_{af} = 10 \cdot \frac{mL}{min}$	$Vdot_{af} = 3.804 \frac{gal}{day}$	AF2290 Feed Rate

$SG_{af} := 1.001$		Specific Gravity of AF2290
$SG_{bd} := 1.041$		Specific Gravity of Slurry
$\rho_{af} := \rho_{water} \cdot SG_{af}$	$\rho_{af} = 8.348 \frac{lb}{gal}$	Density of AF2290
$\rho_{bd} := \rho_{water} \cdot SG_{bd}$	$\rho_{bd} = 8.682 \frac{lb}{gal}$	Density of Slurry
$M_{tank} := V_{tank} \cdot \rho_{bd}$	$M_{tank} = 4.118 \times 10^{6}\, lb$	Mass of Tank Volume
$Mdot_{bd} := Vdot_{bd} \cdot \rho_{bd}$	$Mdot_{bd} = 1.25 \times 10^{6} \frac{lb}{day}$	Mass Flow Rate of Overflow
$Mdot_{af} := Vdot_{af} \cdot \rho_{af}$	$Mdot_{af} = 31.758 \frac{lb}{day}$	Mass Flow Rate of AF2290
$C1_{af} := \frac{Mdot_{af}}{Mdot_{bd}}$	$C1_{af} = 25.402\, ppm$	Concentration of AF2290 at equilibrium
$C2_{af} := C1_{af} \cdot 2$	$C2_{af} = 50.804\, ppm$	Concentration for 2x $Vdot_{af}$
$C3_{af} := C1_{af} \cdot 3$	$C3_{af} = 76.206\, ppm$	Concentration for 3x $Vdot_{af}$

$$percent := \begin{pmatrix} 10 \\ 25 \\ 50 \\ 75 \\ 99 \end{pmatrix} \qquad t(p) := \ln\left(\frac{100}{100 - p}\right) \cdot \frac{V_{tank}}{Vdot_{bd}} \qquad t(percent) = \begin{pmatrix} 0.347 \\ 0.948 \\ 2.283 \\ 4.566 \\ 15.17 \end{pmatrix} day$$

GE Infrastructure
Water & Process Technologies

Customer:	**IPSC**	Date:	**May 1, 2007**
Address:	**Delta, Utah**	Cust. No.	
System:	**Scrubber & AF2290 Feed**	Reported To: CC:	**Brett Kent** **Jerry Hintze** **Dean Wood** **Cindy Jones** **Don Smith**

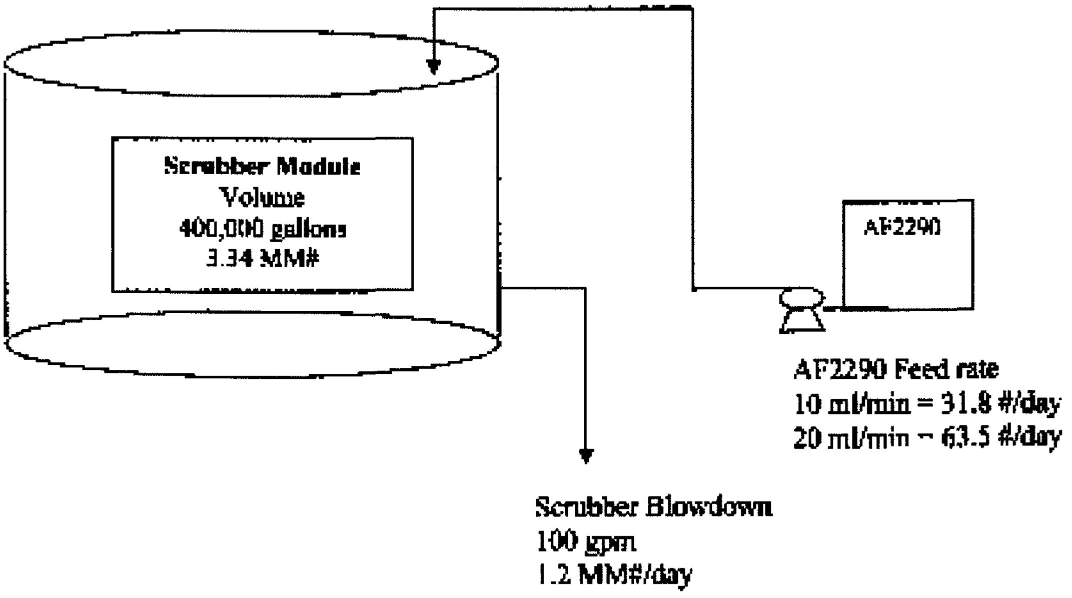
Hello Brett,

During the past 4-8 weeks, IPSC has been able to correlate high feed rates of antifoam (AF2290) to decreased levels of oxidation in the Scrubber modules. In other words, feeding more antifoam than is required to control foam has a negative affect on oxidation in the modules. Because of this fact, it has been determined that improve control of AF2290 is not only desirable from a standpoint of antifoam costs, but also from a standpoint of particle size development and subsequently Thickener performance. With that in mind, we need to use antifoam at a level, which will control foaming, but will not adversely affect oxidation.

Question: What is the best way to control AF2290 feed rate to control foaming, but not adversely affect oxidation?

I suggest we determine the ppm feed rate of AF2290 and relate it to scrubber module blowdown.

Volume - Each Scrubber Module has a volume of ~ 400,000 gallons → 3.34 MM#
Blowdown - The blowdown from the Modules, is projected at an average of 100 gpm → 1.2 MM#/day



The feed of AF2290 is best controlled if it is <u>tied to the rate of blowdown</u>. For instance, if you are blowing down at 100 gpm and feeding AF2290 at 10 ml/min., your feed rate should be → 31.8 # of AF2290/1.2 MM# blowdown = 26.5 ppm. Of course, if your feed rate of AF2290 is 20ml/min, then your daily feed rate would be 53 ppm.

AF2290 Feed Rate (100 gpm blowdown) **10 ml/min → 26.5 ppm**
20 ml/min → 53.0 ppm

Critical Control Residual for AF2290 – It is my understanding, that somewhere between 26.5 ppm and 53 ppm you reach a 'critical control residual', which controls foaming, but does not significantly reduce oxidation.

Question: Is the blowdown flow from the module consistently 100 gpm or variable?

We can use that information to accurately control a 'critical control residual' of AF2290. If blowdown is a constant, we can base control on a specific number, say 100 gpm. If it is variable, that would be important information to provide to the AF2290 pumps for improved control of AF2290 feed rate.

Question: What is the dilution factor for the volume of the Module?

This is a log relationship between volume and blowdown. If you were to add <u>5-gallons of AF2290</u> to a Scrubber Module, you will develop a residual of →
5 gal x 8.35 #/gal →
41.7# & based on module volume, that equals →
41.7#/3.34MM# = **<u>12.5 ppm</u>**.

If you did not add anymore AF2290, that 12.5 ppm you would be reduced by 75% or 3.1 ppm in **<u>3.85 days</u>**.

ln[100/25] = ln 4 → 75%
ln[100/50] = ln 2 → 50%

Dilution by 75% of Volume →
1.386 [vol/bd] →
1.386 [400,000 gal/100 gpm] = 5,544 minutes →
5,544 minutes = **<u>3.85 days</u>**

Conversely, if you feed AF2290 at 10 ml/min, which at 100 gpm blowdown, is <u>26.5 ppm</u>, in 3.85 days you will reach 75% of that feed rate → 26.5 ppm x .75 = <u>19.9 ppm</u>.

<u>Lead Lag Factor (75% of base)</u> → 3.85 days

Based on 100 gpm blowdown from a 400,000 gal module, you have a 3.85 day Lead Lag Factor, which is something we have all observed and would expect. We just never tied an actual timeframe to it.

Brett, these are the calculations we discussed. I hope this is helpful.
Regards,

Norm Hess

INTERMOUNTAIN POWER SERVICE CORP.

Effects of Anti-Foam use in Scrubber Reaction Tanks on Gypsum Purity

D. Bret Kent, PE
bret-k@ipsc.com

Effects of Anti-Foam use in Scrubber Reaction Tanks on Gypsum Purity

Executive Summary

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Test Overview

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Phase 2

Once gypsum purity had been affected by a minimum of 10 percent, the process was reversed as follows: Once Group A reached purity levels of 85 percent or less, the defoamer pumps were shutoff and all manual additions carefully monitored. Once they returned to a purity greater than 93 percent, the test for this group was terminated.

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Test Results

Group A

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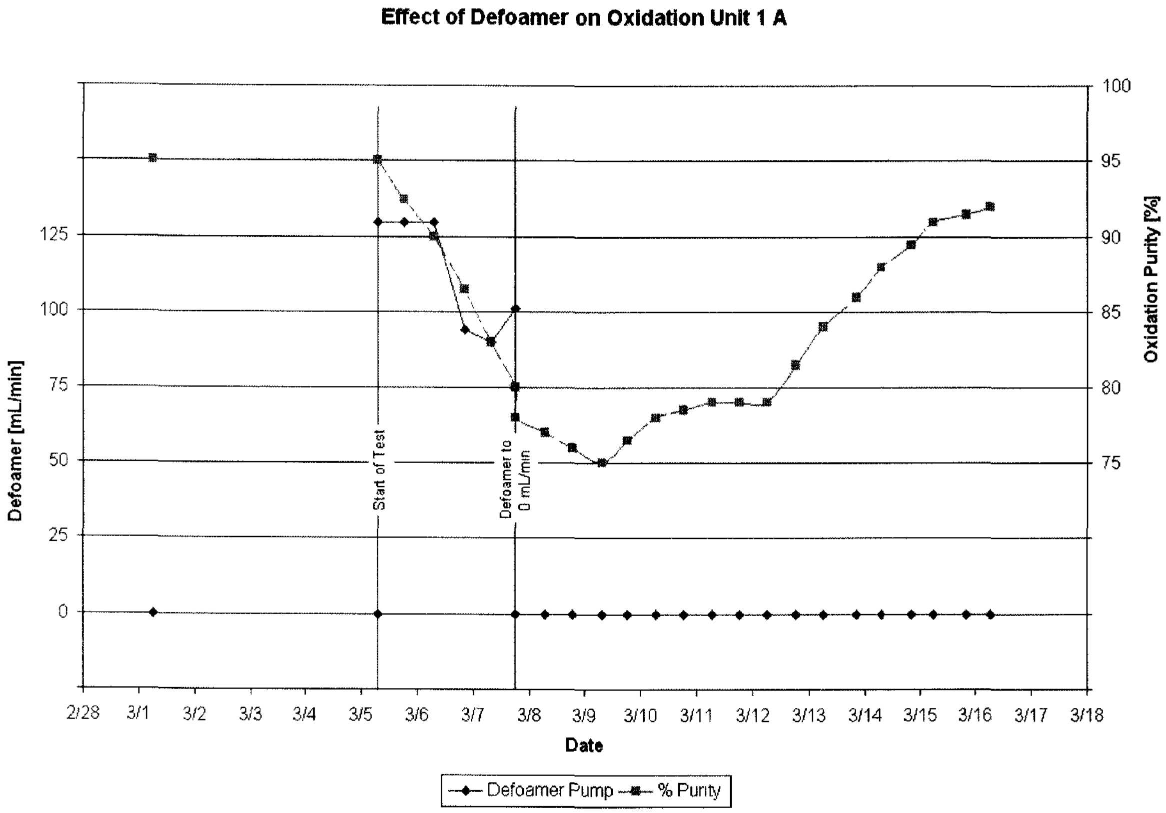

resulted in a significant decrease of oxidation purity.

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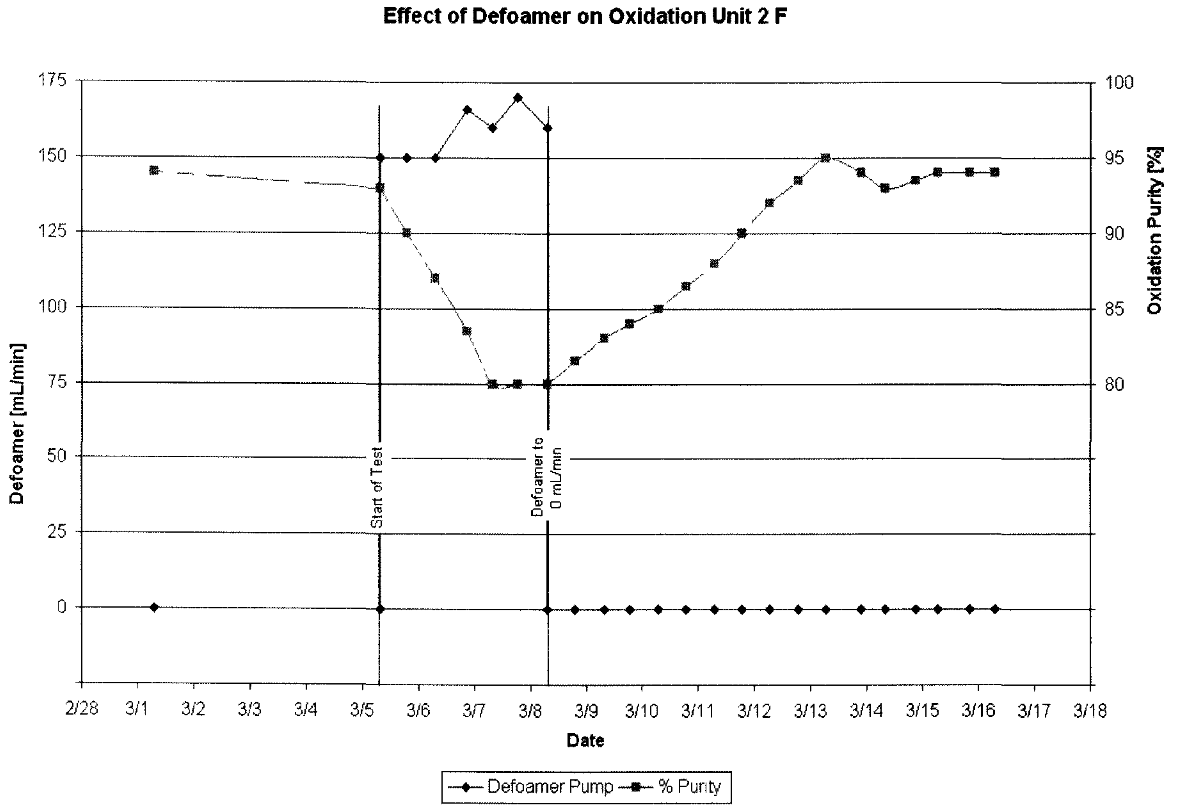
Note the rapid decrease in oxidation purity versus the time required for recovery. This lag indicates a buildup in concentration of AF2290. The time required for recovery is dictated by the turnover rate of the reaction tank.



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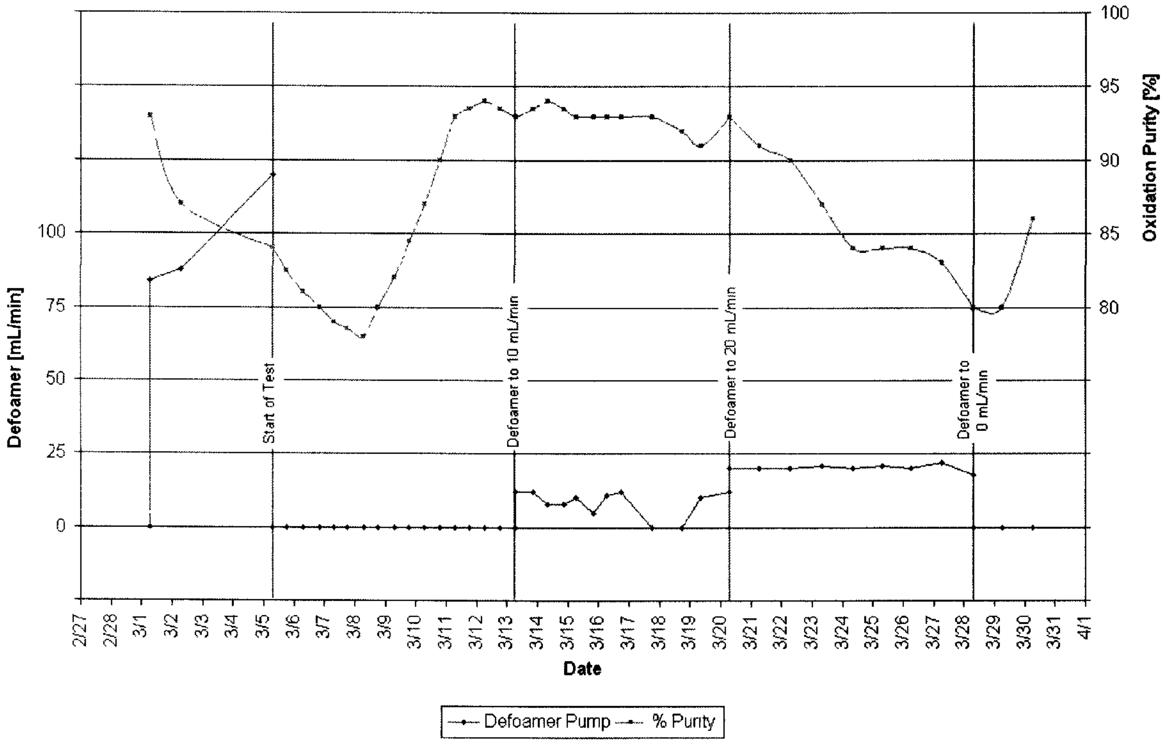
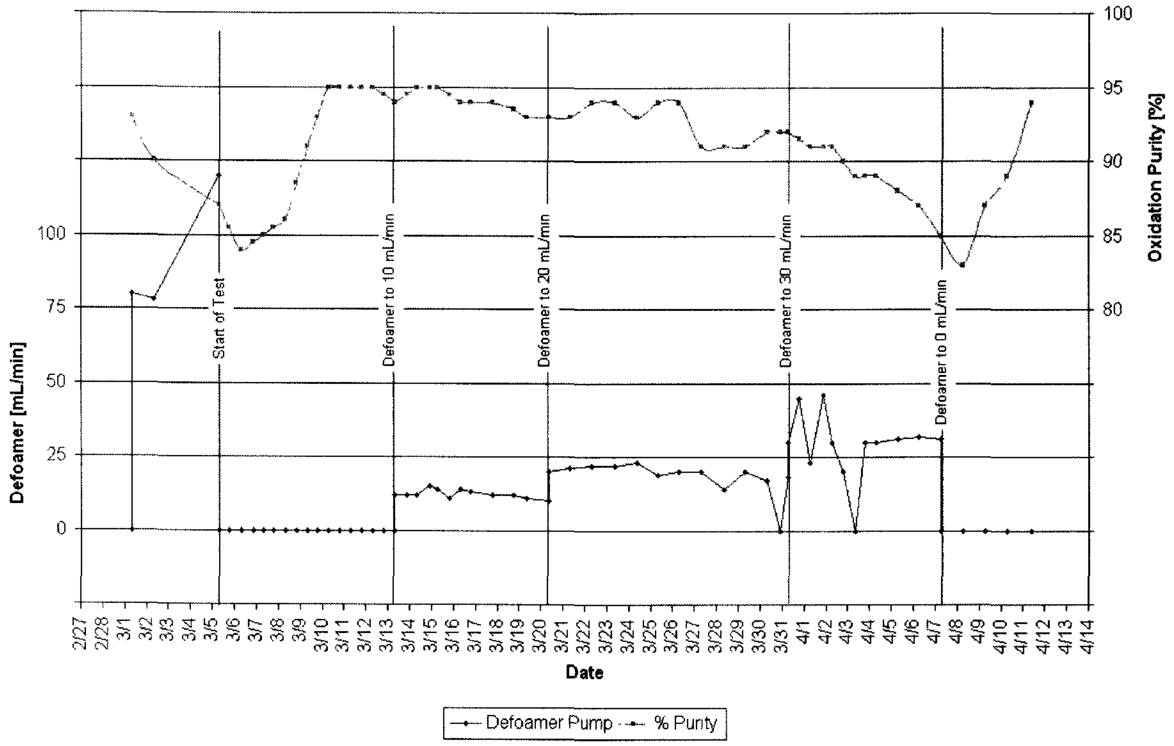
Group B

This group yielded the most interesting results and provides the most information to allow conclusions that will provide operation guidelines for the use of AF2290.



Little to no change was evident in the oxidation purity for an AF2290 addition rate of 10 mL/min to Unit 1D module. Once the addition rate was increased to 20 mL/min, a dramatic change in purity is clearly visible. From this snapshot it appears that under typical operating conditions the deflection point for oxidation purity in relation to the addition rate of AF2290 is between 10 and 20 mL/min.

Effect of Defoamer on Oxidation Unit 2 E



Per the conclusion made from the previous graph (Unit 1D), Unit 2E should have seen similar results for AF2290 feed rates of 20 mL/min. Instead, for a period of nearly a week, oxidation purity cycles up and down. Finally, on March 26 there is a marked change in purity, but then it appears to level out again. Only after the feed rate is increased to 30 mL/min does the trend finally move as expected.

The results of this graph generate more questions than answers. What happened on March 26 to cause the sudden shift in purity? Why would this reaction tank tolerate a higher AF2290 addition rate?

Effects of Oxidation Air and pH

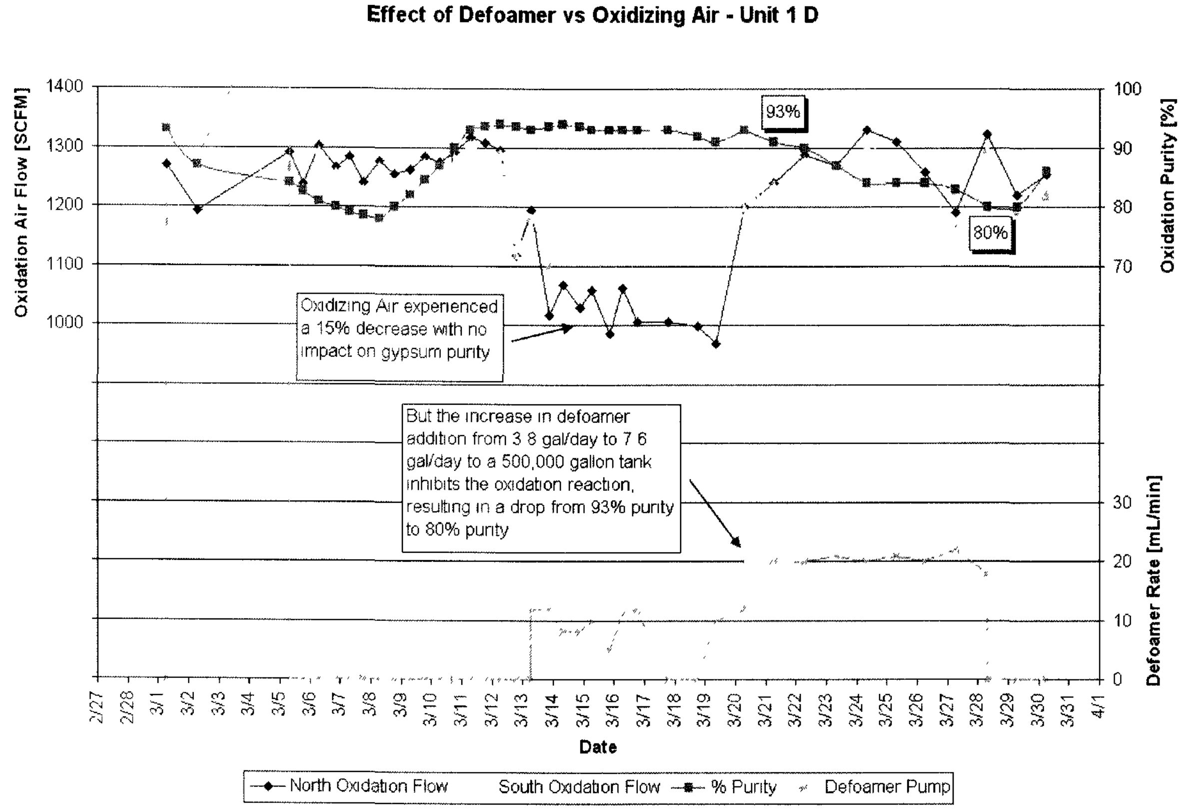
Oxidation purity can be affected by many factors. The factors that can be controlled and are concretely known to directly render change are:

1. Slurry pH
2. Oxidation Air flows
3. Concentration of AF2290

Factors where control is limited or that are currently fixed:

A. Tank Height/Liquid Level

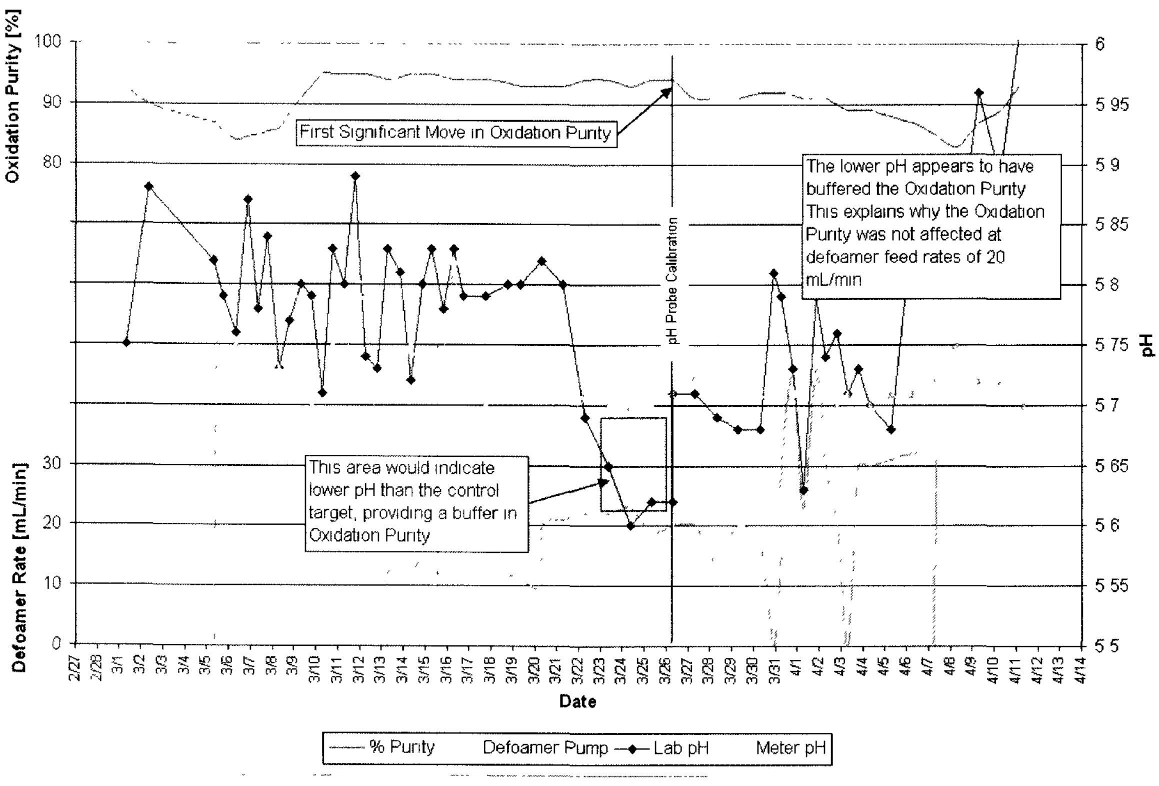
B. Oxidation Air bubble size/distribution



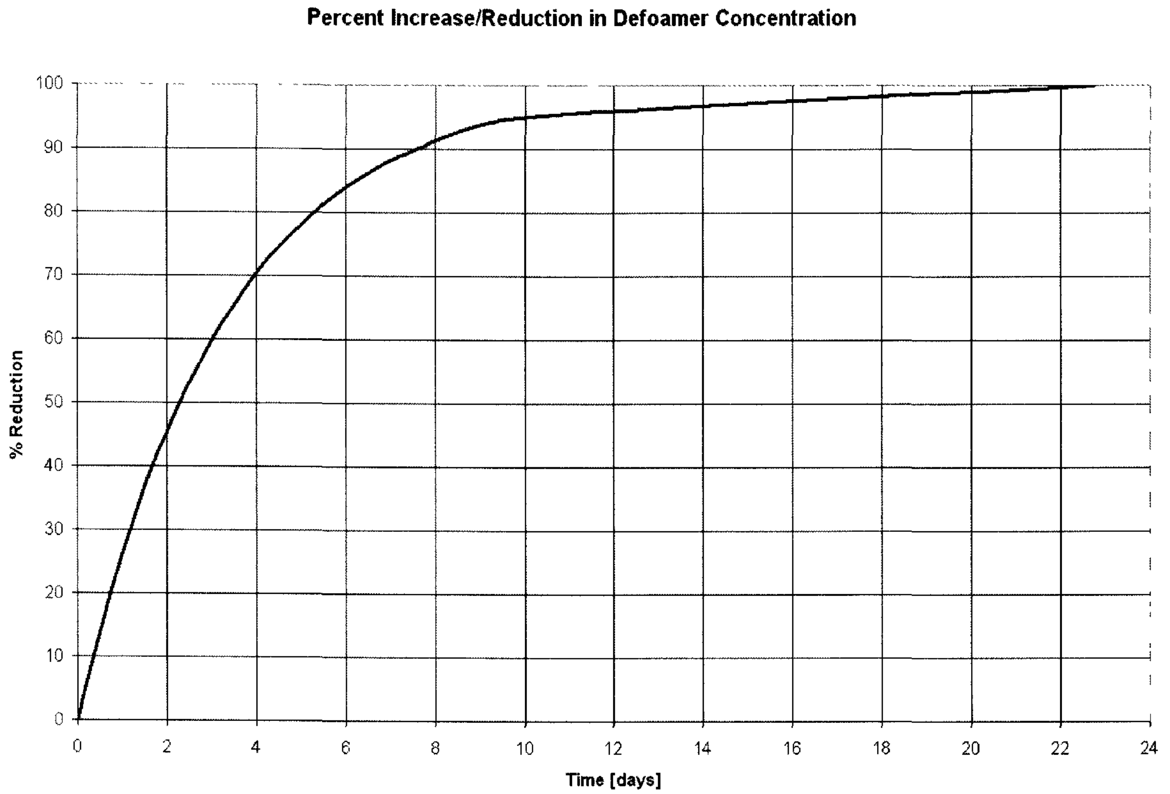
The following graphs will demonstrate the effect of items 1 and 2 from above and attempt to answer the questions raised by the results from Unit 2E.

Notice that while feeding 10 mL/min of AF2290, the oxidation air flow was reduced by 15 percent with little or no effect on the purity. This is more an indication that excess oxidation air is being provided, than anything else. But, it does show that the excess air being provided makes the reaction less susceptible to negative impacts as a result of changes in air flow. This provides assurance that changes in air flow during the course of the test had negligible effect on the observed results.

On March 26, a 0.1 pH point difference between the lab pH and the tank meter pH was noted. I&C Technicians cleaned and calibrated the probe which provided more accurate control of the reaction tank pH. As can be seen below, even after increasing the AF2290 flow rate to 20 mL/min (but prior to the probe calibration) the purity remained unaffected. This appears to be the result of having a significantly lower slurry pH than the desired control target. This low pH resulted in enhanced oxidation purity (lower pH equates to better oxidation purity) which offset the negative impact of the increased defoamer addition. Once the calibration occurred there is an obvious decrease in purity. After this adjustment, the purity stabilized and did not reach the goal of a 10 percent change, so the feed rate was increased to 30 mL/min.



At this point the question still remained, 'why would the defoamer have a greater effect on Unit 1D when compared to Unit 2E?' While it appears that pH had significant impact, the complete answer to this question appears to be outside of the scope of this study. Since all operational data, for these two modules, was similar during the test the answer would seem to lie somewhere in the factors that are harder to control. Because existing level sensors cannot distinguish between foam and liquid level, it is impossible to



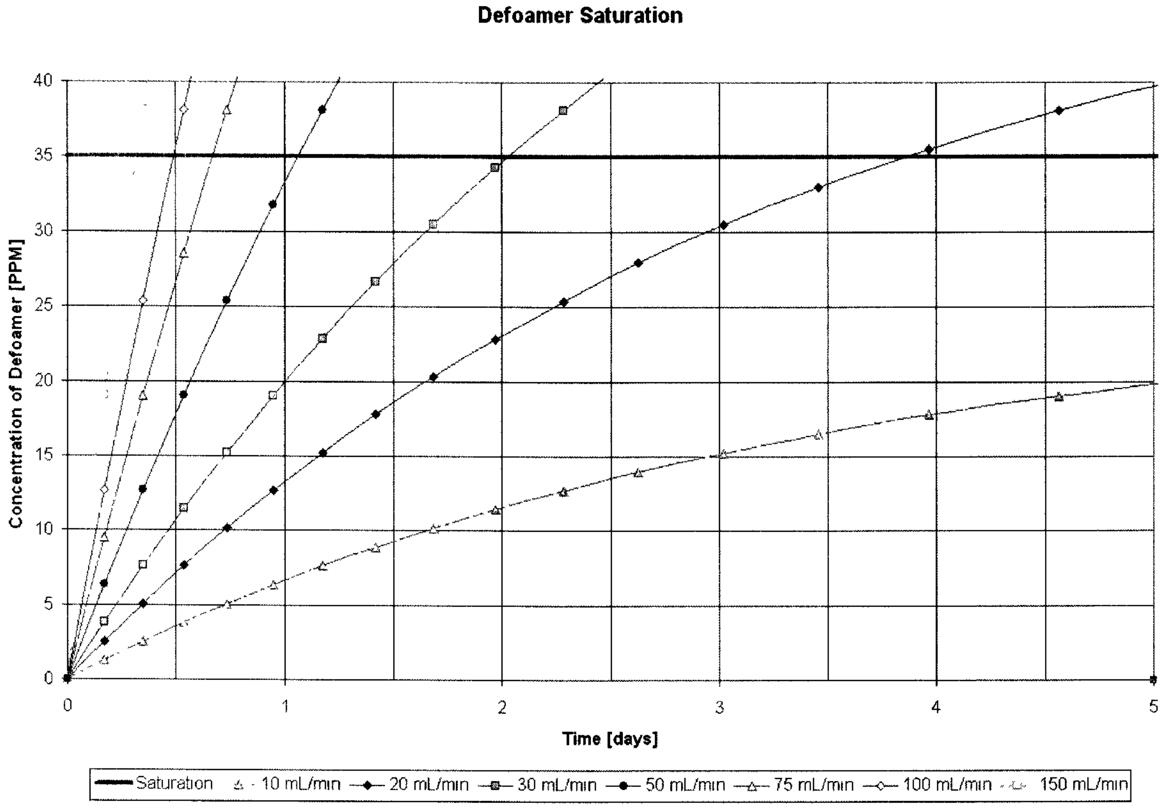
determine if Unit 1D ran a lower liquid level than Unit 2E. It is more likely that distribution nozzles have failed or plugged in Unit 1D, resulting in weaker oxidation kinetics.

Conclusions

The results show a direct correlation between the amount of defoamer added to each scrubber module and it's corresponding gypsum purity levels. While it is not the only process variable that affects gypsum purity it can directly manipulate it. This is simply a question of residence time in the reaction tanks. A careful look at the liquid balance of a reaction tank identifies four (4) main inputs. Mist Eliminator Wash Water, Recovered Water, Limestone Slurry, and the AF2290. The 2 main outputs are evaporation and overflow.

It is apparent that there is an acceptable level of defoamer addition with regards to gypsum purity. If the level of defoamer addition exceeds an allowable concentration, the only alternatives are to reduce the defoamer feed rate or increase the volume of one or all of the inputs.

The following results are adapted from the attached technical letter dated May 1, 2007



from Norm Hess (GE Infrastructure), who is the supplier of the AF2290. The calculations have been modified to account for the actual volume of the reaction tank and density of the slurry (see the attached Mathcad worksheet).

Depending on the blowdown rate of a reaction tank all constant feed additions of AF2290 will eventually achieve an equilibrium state where the concentration will level off.

Addition Rate [mL/min]	10	20	30	50	75	100	150
Equilibrium [PPM]	25.4	50.8	76.2	127.0	190.5	254.0	381.0

The amount of time it takes to reach this equilibrium point is a natural log function. The following graph will illustrate this. This graph assumes constant overflow of 100 gpm.

As an example, if the AF2290 is being added at 10 mL/min it will take approximately 23 days to reach 100 percent equilibrium (25.4 ppm), or 4.5 days to reach 75 percent of equilibrium.

Conversely, if a quantifiable concentration is present in a given reaction tank, at 100 gpm of overflow, it will take 2.3 days to reduce it by 50 percent.

In addition, it is possible to calculate how long it will take before saturation (or the point at which oxidation purity is jeopardized) is achieved. The following graph assumes that it is a single point deflection. Meaning that it does not gradually or linearly affect purity, rather it appears to be a distinct point somewhere between 10 and 20 mL/min where purity is compromised. The data present up to this point would appear to support this idea.

Since an exact number has not been quantified, a value of 35 ppm (the equilibrium concentration point not quite half way between 10 and 20 mL/min) is used to represent a possible deflection point.

This chart correlates nicely with the data collected during the test. At higher feed rates, changes were noted within 24 hours. Addition rates of 10 mL/min did not show any effect on the purity, but once increased to 20 or 30 mL/min it took less than 24 hours to deflect (the added 15 to 20 ppm needed to reach 35 ppm in less than 24 hours correlates to 20 and 30 mL/min respectively).

Recommendations

The recommended application rates provided below should only be implemented when needed and then be turned back off. Manual or batch dosing is preferred.

All application of AF2290 in the scrubber reaction tanks should be minimized and used only when needed. Caution should be taken to monitor cumulative effects for heavy application of defoamer in one (1) or more modules. If more than typical amounts are being applied, request assistance from the lab to monitor oxidation purity numbers.
If the operational situation requires heavy dosing, it should be offset by increasing the other module inputs by an appropriate amount. This proportion requires an approximate 75 gpm increase in reaction tank overflow per every 10 mL/min above and beyond the indicated defoamer rate given in this report.

Adding defoamer should not become a routine part of equipment rounds. Operators should verify the need to add defoamer.

A. Any hand or batch feeding should be done using quantities of one (1) quart or less. Not to exceed **four (4) gallons** cumulative in a 24 hour period. This should be logged and monitored.

B. Continuous addition of 10 mL/min. Could be used indefinitely. Rates should be verified periodically. Be aware that manual addition on top of the 10 mL/min continuous could cause purity to drop off.

C. Continuous addition of 20 mL/min. Not recommended that this be done for more than **six (6) shifts**. This should be logged and monitored to make sure it gets turned back off.

D. Continuous addition of 30 mL/min. Not recommended that this be done for more than **three (3) shifts**. This should be logged and monitored to make sure it gets turned back off. It is not recommended that continuous feed be performed at rates greater than 30 mL/min.

These recommendations apply specifically to the AF2290 product. Conclusions should not be applied to other defoamer products.

Additionally these recommendations are focused on oxidation purity. While the key factor in dewatering is particle size (oxidation purity), it does not directly guarantee successful dewatering. But without good oxidation purity numbers, existing techniques and equipment do not stand a chance at providing effective dewatering.

Plans and Goals

Technical Services is working with GE Infrastructure in order to provide a more efficient means of delivering defoamer to each scrubber reaction tank. This will be a semi-automatic batch feed system, with intentions to make it fully automatic at the earliest convenience. The first steps toward this system are already in motion as bulk tanks and recirc pumps are currently (5-3-07) onsite with trial metering pumps in route.

The semi-automatic system will rely on an Operator pushing a button on a local panel to begin a batch feed into a given module. The pump will then meter out a predetermined quantity of AF2290 and shut off. This system will utilize plastic tubing similar to the existing temporary system, but will eliminate the 300 gallon bins and the unreliable metering pumps.

The automatic system will be triggered off of foam level in the tanks and will only meter out the quantity required to keep foam from reaching the roof of the reaction tank.